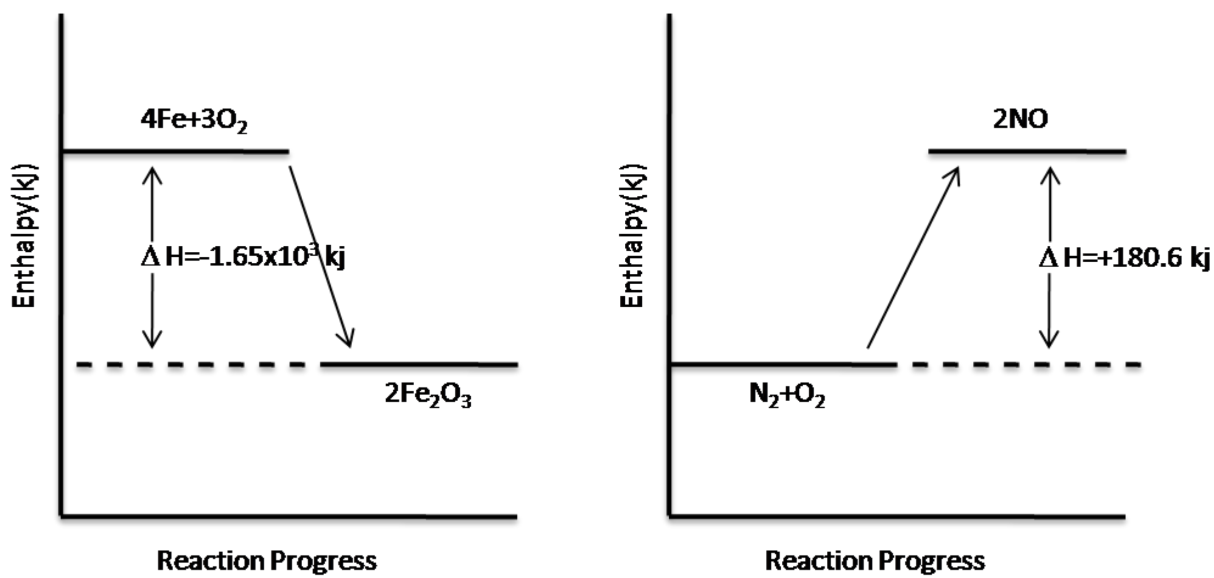
Enthalpy

Thermodynamics

- Study of energy and inter-conversions
- 1st law of thermodynamics—law of conversation of energy
- Two parts of universe:
  - System—portion of universe that is being focused on
  - Surrounding—remaining portion of the universe
  - Three interactions between system and surrounding:
    - Open—system and surroundings are in contact; most common
    - Closed—system doesn't exchange matter with surroundings but may exchange energy
    - Isolate—system will not exchange matter nor energy with the surrounding

Enthalpy

- Change of heat of a system at constant pressure
- Symbolized by ΔH
- Can be either exothermic ($\Delta H < 0$) or endothermic ($\Delta H > 0$)
- Is a state function



Enthalpy Example

- When 1 mole of methane (CH_4) is burned at constant pressure, 890 kJ of energy is released as heat. Calculate ΔH for a process in which a 5.8 g sample of methane is burned at constant pressure.

$$5.8\ g\ CH_4\ x\ \frac{1\ mol\ CH_4}{16.0\ g\ CH_4} = 0.36\ mol\ CH_4$$

$$0.36\ mol\ CH_4\ x\ \frac{-890\ kJ}{1\ mol\ CH_4} = -320\ kJ$$

$$\Delta H = -320\ kJ$$

Bond Energies and Enthalpy

- Can describe energy transfer of whole system or of individual reactions in terms of bonds
- Energy transfer occurs between breaking and making of bonds
  - Bond breaking = endothermic process
  - Bond formation = exothermic process
- $\Delta H = \sum(\text{bonds broken}) - \sum(\text{bonds formed})$

Bond Energies

Average Bond Energies (kJ/mol)

Single Bonds						Multiple Bonds	
H—H	432	N—H	391	I—I	149	C=C	614
H—F	565	N—N	160	I—Cl	208	C≡C	839
H—Cl	427	N—F	272	I—Br	175	O=O	495
H—Br	363	N—Cl	200			C=O*	745
H—I	295	N—Br	243	S—H	347	C≡O	1072
		N—O	201	S—F	327	N=O	607
C—H	413	O—H	467	S—Cl	253	N=N	418
C—C	347	O—O	146	S—Br	218	N≡N	941
C—N	305	O—F	190	S—S	266	C≡N	891
C—O	358	O—Cl	203			C=N	615
C—F	485	O—I	234	Si—Si	340		
C—Cl	339			Si—H	393		
C—Br	276	F—F	154	Si—C	360		
C—I	240	F—Cl	253	Si—O	452		
C—S	259	F—Br	237				
		Cl—Cl	239				
		Cl—Br	218				
		Br—Br	193				

*C=O(CO_2) = 799

Bond Energy Example

- Using the table, calculate ΔH for the reaction of methane with chlorine and fluorine to give Freon-12 (CF_2Cl_2):

$$CH_4\ (g) + 2\ Cl_2\ (g) + 2\ F_2\ (g) \longrightarrow CF_2Cl_2\ (g) + 2\ HF\ (g) + 2\ HCl\ (g)$$

Bonds broken:

4 (C-H) = 4 (413 kJ) = 1652 kJ

2 (Cl-Cl) = 2 (239 kJ) = 478 kJ

2 (F-F) = 2 (154 kJ) = 308 kJ

Total broken = 2438 kJ

Bond Energy Example

Bonds formed:

2 (C-F) = 2 (485 kJ) = 970 kJ

2 (C-Cl) = 2 (339 kJ) = 678 kJ

2 (H-F) = 2 (565 kJ) = 1130 kJ

2 (H-Cl) = 2 (427 k) = 854 kJ

Total = 3632 kJ

$\Delta H = \sum(\text{bonds broken}) - \sum(\text{bonds formed})$

$\Delta H = 2438 \text{ kJ} – 3632 \text{ kJ} = -1194 \text{ kJ}$

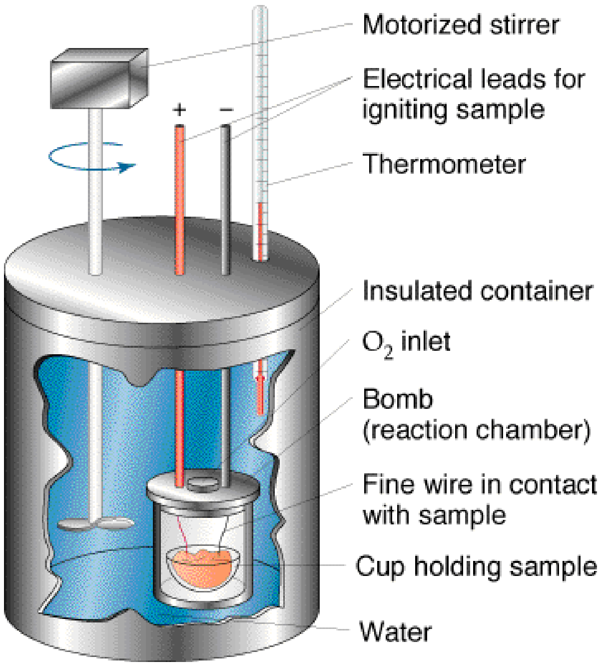
Different Types of Enthalpy

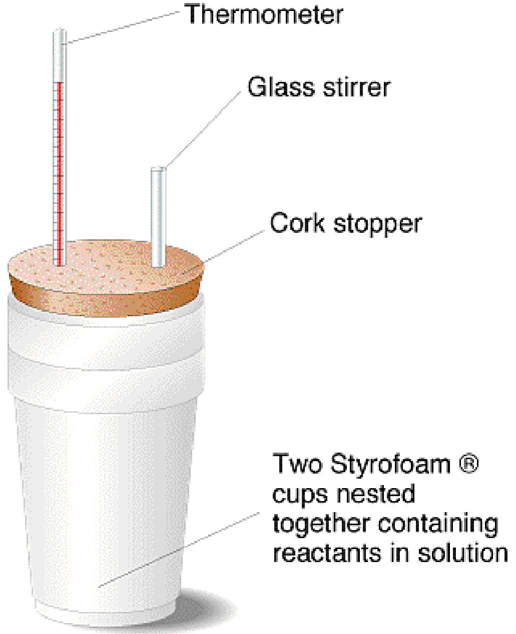
- Heat of fusion (ΔH_{fus})
  - Enthalpy change that occurs in melting a solid at its melting point
- Heat of Vaporization (ΔH_{vap})
  - Energy required to vaporize one mole of a liquid at a pressure of one atmosphere
  - Clausius-Clapeyron equation—determine the vapor pressure of a liquid at a different temperature or to find ΔH_{vap} of a substance

$$\ln\left(\frac{P_1}{P_2}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Calorimetry

- A device used to experimentally determine the heat energy change of a chemical reaction
- Can be carried out at constant pressure (where ΔH is measured) or at constant volume (where ΔE is measured)





Calorimetry

- Amount of heat lost or gained in a reation in a calorimeter depends on:
  - The change in temperature during the reaction
  - The amount of substance present
  - The heat capacity of substance
- Heat capacity—amount of a energy required to change the temperature of an object by 1°C
  - Specific heat capacity = the amount of energy required to change the temperature of 1.0 g of a substance by 1°C
  - Molar heat capacity = the amount of energy required to change the temperature of 1 mole of a substance by 1°C
- Determination of heat released by a reaction:

$$q = m \ x \ s \ x \ \Delta T$$